High peak power nanosecond and picosecond pulse delivery through a hollow-core Negative Curvature Fiber in the green spectral region for micro-machining

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Abstract: We report efficient delivery of nanosecond and picosecond laser pulses in the green spectral region with peak powers of 6.9kW and 3MW respectively through a hollow-core Negative Curvature Fiber and demonstration of fiber-based precision micro-machining.

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1. Introduction

High peak power pulsed lasers operating in the visible spectral range, in particular around 530nm are especially desirable for micro-machining applications. Shorter wavelengths allow focusing to smaller spot diameters and therefore fabricating products with greater precision and quality. However, to widen the application range of these lasers (e.g. to use in robotic devices) a flexible beam delivery system is required. Unfortunately, the green spectral region is outside currently available fiber capability mainly due to fabrication and scattering issues.

In this work we investigate the capacity of a hollow-core microstructured Negative Curvature Fiber (NCF) for the delivery of high peak power, high energy nanosecond (ns) and picosecond (ps) pulses at 532nm and 515nm respectively and the suitability of the fiber-delivered beam for precision machining of various materials. The NCF (Fig. 1(a)) was fabricated by the stack and draw technique. A 16μm diameter hollow core corresponds to a 9μm mode field diameter. Attenuation at 515nm and 532nm was measured to be 0.23dB/m and 0.21dB/m respectively.

2. Nanosecond and picosecond pulse delivery for micro-machining applications

The ns pulse source used was a Spectra Physics Q-switched Nd:YVO_4 laser at 532nm (M^2=1.2) providing 55ns pulses at a 15kHz rep. rate, pulse energy of 0.65mJ and a peak power of 12kW (9.8W avg.). Laser pulses of 0.38mJ and peak power 6.9kW, were delivered through a 9.5m NCF with a coupling efficiency < 91% (excluding fiber loss) without damaging the fiber. The transmission of ns pulses was limited only by the laser parameters.

Picosecond pulse delivery was performed with a TRUMPF TruMicro ps laser (M^2=1.3) at 515nm providing 6ps pulses at a 400kHz rep. rate, pulse energy of up to 62μJ and peak power of 10.3MW (25W avg.). The laser beam was coupled into 9.5m of NCF with a coupling efficiency of 86% which allowed delivery of pulses with energies of 18μJ and peak power of 3MW (7.3W avg.). Damage to the fiber input end-facet occurred at pulse energies of 50μJ with peak power of 8.3MW (peak power density of 10.6TWcm^{-2}). The fiber in both cases demonstrates a stable output in comparison with previously reported NCF for guidance at 1μm [1].

We have also investigated the suitability of an NCF-delivered beam for micro-machining purposes. Ns delivered pulses have been demonstrated to cut Aluminum and mark Titanium as shown in Fig. 1(b) and 1(c) respectively. Machining of glass with fiber-delivered ps pulses is currently under investigation.

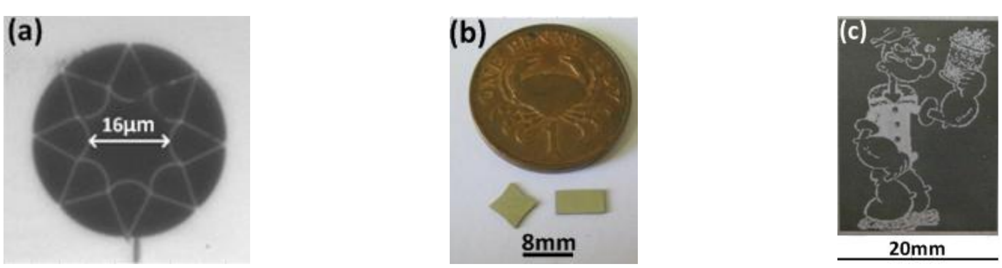

Fig. 1. (a) SEM image of fabricated NCF; (b) ns cutting of 0.3mm thick Aluminum; (c) ns marking in Titanium.

3. References

[1]P. Jaworski, F. Yu, R.R.J. Maier, W. J. Wadsworth, J. C. Knight, J. D. Shephard, and D. P. Hand, "Picosecond and nanosecond pulse delivery through a hollow-core Negative Curvature Fiber for micro-machining applications," Opt. Express **21**, 22742-22753 (2013).